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(54) [Title of the Invention] Electric deionizer

(57) [Abstract]

[Issue] To prevent a reduction in performance of an ion conductive substance which fills the electrode chambers of an electric deionizer, thereby enabling long-term operation.

[Means of Resolution] An electric deionizer comprising: an anode chamber 17 having an anode 11; a cathode chamber 18 having a cathode 12; and enriching chambers 15 and desalination chambers 16 which are alternately formed by a plurality of anion exchange membranes 13 and cation exchange membranes 14 which are alternately arranged between the anode chamber 17 and cathode chamber 18. The anode chamber 17 and cathode chamber 18 are filled with an ion conductive substance, and de-anionized water or pure water passes through the anode chamber 17, while de-cationized water or pure water passes through the cathode chamber 18.

raw water

11: anode

12: cathode

13: A membrane

14: C membrane

15: enrichment chamber

16: desalination chamber

17: anode chamber

18: cathode chamber

waste water

enriched water

waste water

production water

[Scope of the Patent Claims]

[Claim 1] An electric deionizer comprising: an anode chamber having an anode; a cathode chamber having a cathode; and enriching chambers and desalination chambers which are alternately formed by a plurality of anion exchange membranes and cation exchange membranes which are alternately arranged between the anode chamber and cathode chamber; and

an enrichment chamber lies adjacent to the anode chamber with a cation exchange membrane interposed, and an enrichment chamber lies adjacent to the cathode chamber with an anion exchange membrane interposed,

wherein the anode chamber and the cathode chamber are filled with an ion conductive substance;

de-anionized water or pure water passes through the anode chamber; and

de-cationized water or pure water passes through the cathode chamber.

[Claim 2] The electric deionizer as claimed in claim 1, wherein the ion conductive substance in the anode chamber is an ion exchange resin and/or activated carbon, and the ion conductive substance in the cathode chamber is an ion exchange resin.

[Claim 3] The electric deionizer as claimed in claim 2, wherein a heavy metal is supported by the ion conductive substance.

[Claim 4] The electric deionizer as claimed in any one of claims 1 to 3, wherein the cathode chamber outflow water is used as the anode chamber inflow water.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention] The present invention relates to an electric deionizer, and in particular the invention relates to an electric deionizer in which the electrical efficiency is

improved by filling the electrode chambers (anode chamber and cathode chamber) thereof with an ion conductive substance, and a reduction in the performance of the ion conductive substance which fills the electrode chambers of the electric deionizer is prevented, thereby enabling long-term operation.

[0002]

[Prior Art] Electric deionizers such as that shown in Figure 2, in which enrichment chambers 15 and desalination chambers 16 are alternately formed by a plurality of anion exchange membranes (A membranes) 13 and cation exchange membranes (C membranes) 14 which are alternately arranged between electrodes (anode 11, cathode 12), and in which the desalination chambers 16 are filled with a mixture or stacked layers of anion exchange material or cation exchange material comprising ion exchange resins, ion exchange fibers or graft exchange material etc., are widely used in the production of deionized water for use in various industrial and commercial fields and research facilities, including semiconductor production plants, liquid crystal production plants, the pharmaceutical industry, the food industry, and the power industry, among others (Japanese Patents 1782943, 2751090, 2699256). In Figure 2, 17 is an anode chamber and 18 is a cathode chamber, and spacers are generally provided.

[0003] Ions which flow into the desalination chambers 16 react with the ion exchange material due to the affinity, concentration and mobility of these ions, which then move through the ion exchange material in the direction of the potential gradient, and move across the membrane, and a neutral charge is maintained in all of the chambers. The ions are decreased in the desalination chambers 16 and are enriched in the adjacent enrichment chambers 15 because of the characteristics of the membranes which are selectively permeable to ions, and because of the directivity of

the potential gradient. That is to say, cations pass through the cation exchange membranes 14, and anions pass through the anion exchange membranes 13 so as to be concentrated in the enrichment chambers 15. Consequently, deionized water (pure water) is recovered from the desalination chambers 16 as production water.

[0004] Raw water is introduced into the desalination chambers 16 and enrichment chambers 15 and deionized water (pure water) is recovered from the desalination chambers 16. Meanwhile, some of the enriched water which has been enriched with the ions flowing out from the enrichment chambers 15 is circulated to the inlet side of the enrichment chambers 15 by means of a pump (not depicted) in order to raise the water recovery rate, and the remainder is discharged to outside the system as waste water in order to prevent ion enrichment inside the system.

[0005] Moreover, electrode water is also allowed to pass through the anode chamber 17 and cathode chamber 18, and this electrode water is replenished with conductive water having electrical conductivity of several tens of μS/cm or greater, or an NaCl electrolyte or similar is added thereto in order to ensure conductivity.

[0006] Japanese Unexamined Patent Application Publication H10-43554 proposes filling the cathode chamber with conductive particles, and USP 5,868,915 proposes filling the electrode chambers with an ion conductive substance; when the electrode chambers are filled with an ion conductive substance in this way, the ion conductive substance makes it possible to ensure conductivity in the electrode chambers, and therefore it is no longer necessary to add the electrolyte to the electrode water or to replenish same with conductive water.

[0007]

[Issues to be Resolved by the Invention] With electric deionizers in which the electrode chambers are filled with an ion conductive substance, there are advantages in that the electrical resistance is low and the electrical efficiency is high in the electrode chambers, but there are problems in that the ion conductive substance deteriorates because of oxidizing agents such as chlorine which are generated in the anode chamber; there are further problems in that there is a reduction in performance of the ion conductive substance because of scale deposition in the cathode chamber, and also in that operation cannot be continued over prolonged periods of time.

[0008] The present invention aims to resolve these problems by providing an electric deionizer in which reductions in performance of the ion conductive substance which fills the electrode chambers are prevented, thereby enabling long-term operation.

[0009]

[Means of Resolving the Issues] The electric deionizer according to the present invention comprises: an anode chamber having an anode; a cathode chamber having a cathode; and enriching chambers and desalination chambers which are alternately formed by a plurality of anion exchange membranes and cation exchange membranes which are alternately arranged between the anode chamber and cathode chamber; and an enrichment chamber lies adjacent to the anode chamber with a cation exchange membrane interposed, and an enrichment chamber lies adjacent to the cathode chamber with an anion exchange membrane interposed, wherein the anode chamber and the cathode chamber are filled with an ion conductive substance; de-anionized water or pure water passes through the anode chamber; and de-cationized water or pure water passes through the cathode chamber.

[0010] The electrode chambers of the electric deionizer according to the present invention are filled with an ion conductive substance, and therefore the electrical resistance is low and the electrical efficiency is high in the electrode chambers.

[0011] In the cathode chamber of the electric deionizer, OH^- is generated by the reaction in (1) below. Then, when the electrode water which contains cations passes through the cathode chamber which is filled with the ion conductive substance, calcium scale is generated in the cathode chamber by the reaction in (2) below, and the calcium scale generating reaction is promoted by OH^-.

$$2H_2O + 2e^- \rightarrow 2OH^- + H_2 \qquad ...(1)$$
$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3 \qquad ...(2)$$

[0012] Consequently, when water containing Ca^{2+} ions passes through the cathode chamber which is filled with the ion conductive substance, there is a reduction in the performance of the ion conductive substance because of the scale which is generated in the cathode chamber.

[0013] In the present invention, de-cationized water, from which Ca^{2+} ions or the like have been removed, or pure water passes through the cathode chamber, and therefore scale is prevented from being generated and there is no reduction in performance of the ion conductive substance.

[0014] Furthermore, the following reactions in (3) and (4) take place in the anode chamber, where chlorine is generated and the ion conductive substance such as an ion exchange resin undergoes oxidative degradation caused by the generation of chlorine.

$$2H_2O \rightarrow 4H^- + 4e^- + O_2 \qquad ...(3)$$
$$2Cl^- \rightarrow 2e^- + Cl_2 \qquad ...(4)$$

[0015] In the present invention, de-anionized water, from which Cl^- ions or the like have been removed, or pure water passes through the anode chamber, and therefore chlorine generation is prevented and oxidative degradation of the ion conductive substance is prevented.

[0016] Ion exchange resin may be cited as an ion conductive substance for filling the cathode chamber and the anode chamber, but ozone (O_3) which has a strong oxidizing power is also generated besides chlorine in the anode chamber, and therefore it is effective to use activated carbon which has a reducing action; the activated carbon may be used alone or ion exchange resin and activated carbon may be mixed together for use.

[0017] Furthermore, if a substance which supports a heavy metal is used as the ion conductive substance, it is possible to achieve an effect whereby the electrical resistance is further reduced because the heavy metal acts to increase conductivity, and this is preferred.

[0018] Furthermore, the cathode chamber outflow water contains hydrogen which is generated in the reaction (1) above. The cathode chamber outflow water containing this reducing hydrogen serves as the anode chamber inflow water, and this means that it is possible to reduce and remove the oxidizing substances generated in the anode chamber, and it is possible to more reliably prevent oxidative degradation of the ion conductive substance in the anode chamber. The cathode outflow water exits the cathode chamber and passes through the anion exchange membranes whereby the anion component such as Cl^- is removed therefrom, which means that this water can be effectively utilized as water from which the anion component has been removed that passes through the anode chamber.

[0019]

[Mode of Embodiment of the Invention] A mode of embodiment of the present invention will be described below in detail with reference to the figures.

[0020] Figure 1 is a schematic view in cross section of the electric deionizer which represents a mode of embodiment of the present invention.

[0021] Like the conventional electric deionizer shown in Figure 2, this electric deionizer is a device in which enrichment chambers 15 and desalination chambers 16 are alternately formed by a plurality of anion exchange membranes (A membranes) 13 and cation exchange membranes (C membranes) 14 which are alternately arranged between electrodes (anode 11, cathode 12), and in which the desalination chambers 16 are filled with a mixture or stacked layers of anion exchange material or cation exchange material comprising ion exchange resins, ion exchange fibers or graft exchange material etc.

[0022] The anode chamber 17 and cathode chamber 18 are both adjacent to enrichment chambers 15, with a cation exchange membrane 14 and an anion exchange membrane 13 interposed, respectively, and the anode chamber 17 and cathode chamber 18 are filled with an ion conductive substance.

[0023] Raw water is introduced into the desalination chambers 16 and enrichment chambers 15 and production water (pure water) is recovered from the desalination chambers 16. Some of the production water is pumped to the inlet side of the cathode chamber 18 as cathode chamber 18 inflow water. The cathode chamber 18 outflow water is pumped to the inlet side of the anode chamber 17, and the anode chamber 17 outflow water is discharged to outside the system as waste water. Some of the enriched water which has been enriched with the

ions flowing out from the enrichment chambers 15 is circulated to the inlet side of the enrichment chambers 15, and the remainder is discharged to outside the system as waste water.

[0024] With this electric deionizer, the anode chamber 17 and cathode chamber 18 are filled with the ion conductive substance, and therefore the electrical resistance is low and the electrical efficiency is high in the electrode chambers.

[0025] Ion exchange material such as ion exchange resin, ion exchange fibers or graft exchange material may be cited as ion conductive substances; the ion conductive substance used in the cathode chamber 18 is preferably a mixed ion exchange material such as a mixed bed ion exchange resin comprising anion exchange resin and cation exchange resin, or an anion exchange material alone such as anion exchange resin.

[0026] On the other hand, the ion conductive substance used in the anode chamber 17 is preferably a mixed ion exchange material such as a mixed bed ion exchange resin comprising anion exchange resin and cation exchange resin, or a cation exchange material alone such as cation exchange resin, or a mixture of activated carbon and these ion exchange materials.

[0027] Filling the anode chamber 17 with activated carbon makes it possible to prevent oxidative degradation in the anode chamber 17, by virtue of the reducing action of the activated carbon, as was described above, and this is preferable.

[0028] Furthermore, one or two or more types of heavy metals such as palladium, iron and manganese may be supported by some or all of the ion exchange materials such as the ion exchange resins which fill the cathode chamber 18 and anode chamber 17; when such heavy metals

are supported, an effect is demonstrated whereby the electrical resistance is further reduced. In this case, no particular limitation is imposed on the amount of heavy metal supported, but this amount is preferably around 0.5 - 10 wt% with respect to the ion exchange material.

[0029] Furthermore, when the ion exchange materials are used in conjunction with activated carbon, and when the ion exchange materials support heavy metals, the electrode chambers are filled with the ion exchange material which supports activated carbon or heavy metals along the surface of the electrode plates and this is effective in favoring reaction.

[0030] With the electric deionizer in Figure 1, production water (pure water) flows through the cathode chamber 18 which is filled with the ion conductive substance in this way, and therefore scale is prevented from being generated in the cathode chamber 18, and so a reduction in the performance of the ion conductive substance caused by the scale is prevented.

[0031] Furthermore, the cathode chamber 18 outflow water which flows through the anode chamber 17 is pure water flowing into the anode chamber 17, and it does not contain an anion component, and moreover it contains reducing hydrogen which is generated in the electrode reaction inside the cathode chamber 18, and therefore it is possible to prevent oxidative degradation of the ion conductive substance in the anode chamber 17.

[0032] Moreover, the electric deionizer shown in Figure 1 is one example of a mode of embodiment of the electric deionizer according to the present invention, but the present invention is not limited to the device shown in the figure, provided that any variations remain within the scope of the invention.

[0033] For example, with the electric deionizer shown in Figure 1, the enrichment chambers 15 are not filled with the ion conductive substance, but the enrichment chambers may equally be filled with an ion exchange material or an ion conductive substance such as activated carbon or heavy metal. Furthermore, with the electric deionizer shown in Figure 1, production water serves as the cathode chamber 18 inflow water, but pure water from a separate system or water from which the cation component has been removed by processing raw water in a cation exchange resin column (soft water) may equally be used as the cathode chamber 18 inflow water. Furthermore, instead of using the cathode chamber 18 outflow water for the anode chamber 17 inflow water, it is feasible to use production water or pure water from a separate system or water from which the anion component has been removed by processing raw water in an anion exchange resin column. It is not necessarily the case that some of the enriched water has to be circulated, and when the quality of the production water is more of a priority than the water recovery rate, raw water may be allowed to flow through for a time in any direction.

[0034]

[Effects of the Invention] As described above, the present invention provides an electric deionizer in which the electrical efficiency is improved by filling the electrode chambers thereof with an ion conductive substance, and a reduction in the performance of the ion conductive substance which fills the electrode chambers of the electric deionizer can be prevented, thereby enabling long-term operation.

[Brief Description of the Figures]

[Figure 1] is a schematic view in cross section of an electric deionizer which represents a mode of embodiment of the present invention; and

[Figure 2] is a schematic view in cross section which represents a conventional electric deionizer.

[Key to Symbols]

11 anode
12 cathode
13 anion exchange membrane (A membrane)
14 cation exchange membrane (C membrane)
15 enrichment chamber
16 desalination chamber
17 anode chamber
18 cathode chamber

[Figure 1]

raw water
11: anode
12: cathode
13: A membrane
14: C membrane
15: enrichment chamber
16: desalination chamber
17: anode chamber
18: cathode chamber
waste water
enriched water
waste water
production water

[Figure 2]

raw water
electrode water
13: A membrane
14: C membrane
electrode water
11: anode
12: cathode
15: enrichment chamber
16: desalination chamber
17: anode chamber

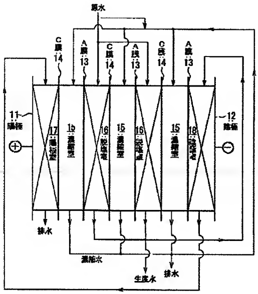
18: cathode chamber

enriched water

production water

waste water

【図1】



【図2】